Introduction
We provided the opportunity for a small number of people to remotely attend the ACM CHI 2017 conference via telepresence technologies. Our goal was to increase access to the conference for remote participants who would otherwise be unable to attend due to mobility impairments, chronic health issues, or temporary travel limitations. This telepresence experience builds on past telepresence attendance setups at other conferences, including Ubicomp/ISWC 2014, ACM CSCW 2016, and ACM CHI 2016.

Remote attendees used a telepresence robot, BeamPro, made by Suitable Technologies to attend CHI 2017. We rented 14 BeamPros (hereafter called Beams) from Event Presence to accommodate remote attendance. The robots allowed remote attendees to appear on the screen, maneuver in the conference venue, attend talks, and mingle with other attendees.

The following reports on the telepresence attendance experience at CHI 2017 based on our observations as Telepresence Chairs; reports from remote attendees using a post-conference survey that asked remote attendees for feedback on their experience (14 responses); and, reports from student volunteers in a post-conference survey (12 responses).

Remote Attendees
We advertised remote attendance on the CHI 2017 website, the CHI Meta Facebook Group, the CHI-Announcements mailing list, and through emails sent to colleagues. In total, we received 20 applications to attend CHI remotely. Application numbers were somewhat low until the final two weeks before CHI. 13 of 20 applications came before our application deadline (March 31, 2017), approximately one month before the conference. We did an additional advertisement push in the final two weeks before CHI and received 7 more applications.
Five people declined to remotely attend after applying because of the associated registration cost.

In the end, sixteen people attended the conference via telepresence robot. Table 1 shows details about each remote attendee, including the number of "Days" that they booked the Beam to attend the conference and whether or not they participated in the Main Conference (Monday-Thursday), Workshops, or other activities. 2 people had accessibility needs, 6 had Visa/Border issues, and 8 were unable to attend for other reasons (cost, time, etc.). In addition to these attendees, we had 3 people from the media attend portions of CHI (not included in Table 1).

Three people (one from India, two from Nigeria) applied to attend remotely via telepresence because of Visa/Border issues but were unable to because their Internet connection did not offer a large enough bandwidth to support the Beams.

<table>
<thead>
<tr>
<th>Location</th>
<th>Role</th>
<th>Reason</th>
<th>Days</th>
<th>Activities</th>
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<tbody>
<tr>
<td>1</td>
<td>Canada</td>
<td>Graduate Student</td>
<td>4</td>
<td>Main Conference</td>
</tr>
<tr>
<td>2</td>
<td>Canada</td>
<td>Graduate Student</td>
<td>4</td>
<td>Main Conference</td>
</tr>
<tr>
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<td>Canada</td>
<td>Graduate Student</td>
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<td>Main Conference</td>
</tr>
<tr>
<td>4</td>
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<td>Graduate Student</td>
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<td>Main Conference</td>
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<td>5</td>
<td>France</td>
<td>Faculty</td>
<td>1</td>
<td>Diversity Lunch only</td>
</tr>
<tr>
<td>6</td>
<td>France</td>
<td>Graduate Student</td>
<td>1</td>
<td>Paper presentation only</td>
</tr>
<tr>
<td>7</td>
<td>Germany</td>
<td>Faculty</td>
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<td>Main Conference</td>
</tr>
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<td>Workshop, CHI4GOOD</td>
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<td>Ireland</td>
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<tr>
<td>16</td>
<td>USA</td>
<td>Faculty</td>
<td>3</td>
<td>Main Conference</td>
</tr>
</tbody>
</table>

Table 1: Remote Attendees

Beams were dedicated to an individual person for each entire day. Despite having more remote attendees (16) than available Beams (14), at any one time the maximum amount of Beams being used concurrently was six. This occurred even though all 14 Beams were booked on Monday (the first day of the main conference), 10 were booked on Tuesday, 9 were booked on Wednesday, and 9
were booked on Thursday. Attendees limited their use of the Beams due to time zone differences (those in Europe had difficulties attending later in the day because it was the night in Europe), interest in only specific sessions, and fatigue from the cognitive load needed to pilot a Beam. For example, it was difficult for some participants to pilot a Beam for periods longer than 2-3 hours at a time. Thus, even though Beams were dedicated to a person for an entire day, this type of booking was generally not needed. Instead, remote attendees typically required bookings of several hours in duration only. In rare cases did users attend for periods of time longer than several hours at a time.

Registration Costs
Remote attendees paid full conference registration rates at the early bird rate:
- $250 USD to attend a workshop (plus the need to register for a single day)
- $300 USD to attend a single day of the conference
- $400 USD to attend the full conference as a student
- $800 USD to attend the full conference as a non-student

In comparison, remote attendees at CHI 2016 paid $75 USD per day of usage because the telepresence setup was still considered experimental (Rae and Neustaedter, 2017). At CHI 2016, remote attendees picked sessions that they wanted to use the Beams for. In total, CHI 2016 had 33 remote attendees sharing 10 Beams. Thus, remote attendance numbers dropped for CHI 2017 compared to CHI 2016. This is despite the political climate in the United States at the time and concerns about a possible travel ban for people from particular countries in the world.

High remote attendance numbers at CHI 2016 compared to CHI 2017 may possibly be from a novelty factor for CHI 2016, which was the first time remote attendance was offered via Beams at CHI. Responses from the remote attendee survey also suggest that price was likely a strong factor in remote attendance numbers. Table 2 shows attendee responses when asked what they felt a fair price would be for remote attendance - Column 2 shows the actual price charged and Columns 3-6 show participants' chosen "fair" price. Rows showing student rates were compiled using only numbers from student respondents (n=3) for our post-conference survey. Rows showing non-student rates were compiled using only numbers from non-student respondents (n=8).

<table>
<thead>
<tr>
<th>What do you feel would be a fair price?</th>
<th>Actual</th>
<th>Average</th>
<th>Median</th>
<th>Minimum</th>
<th>Maximum</th>
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</thead>
<tbody>
<tr>
<td>Student Single Day</td>
<td>$300</td>
<td>$83 +/- $30</td>
<td>$100</td>
<td>$50</td>
<td>$100</td>
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<tr>
<td>Non-Student Single Day</td>
<td>$300</td>
<td>$188 +/- $80</td>
<td>$175</td>
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<td>$300</td>
</tr>
<tr>
<td>Student Full Conference</td>
<td>$400</td>
<td>$350 +/- $87</td>
<td>$400</td>
<td>$250</td>
<td>$400</td>
</tr>
<tr>
<td>Non-Student Full Conference</td>
<td>$800</td>
<td>$564 +/- $189</td>
<td>$550</td>
<td>$300</td>
<td>$800</td>
</tr>
</tbody>
</table>

Table 2: Cost of remote attendance compared to participants' desired pricing

These numbers show that that student and non-student rates for a single day registration felt high to remote attendees, while the student rate for the full conference felt fair. The non-student rate for the full conference felt somewhat high to remote attendees as well. Some commented on the price in the post-conference survey in terms of things they would change:
"I would give people a discount on registration since the experience is not the same as the in person, I would also make the slides for all presenters available to presenters or offer live streaming of talks instead"

We asked what pricing model remote attendees thought was best, e.g., pay per day, pay per session, pay for entire event, etc. Question responses were open-ended. Within their response, 5 respondents mentioned a means to pay per day, 6 respondents mentioned paying per session, 1 person wanted to pay for the entire event, and 4 respondents mentioned all options (paying per day, event, and session).

"I think per session might be the most useful, because sustaining on the Beam all day is surprisingly taxing. I would be less inclined to stay for the entire day if I could do a "pay as you go" kind of thing."

"In many cases, the motive for telepresence could be the cost of travel and therefore there would be advantages to the possibility of attendance at individual sessions/days or indeed a 'top-up' pass for a number of hours/sessions"

"Pay per day, but make it much cheaper as it is still inconvenient to use, the quality is ok but far from perfect. Specifically in a different time zone usage is naturally limited to a few hours a day. I stayed up until 3am in the morning but that was pretty challenging. Rooms need to be better prepared for beams entering the room and leaving the room. As it was today it was difficult to come or leave between talks."

The 14 Beams were rented from Event Presence for a rate of $XXXX USD. This was a heavily discounted rate. For this cost, Event Presence brought the Beams from California to Denver and performed initial setup work on-site (e.g., connecting them to the WiFi network). This service was the same as performed at CHI 2016; no new services were added though Event Presence was testing location tracking software for the Beams for future events. Revenue generation from registrations was $XXXX USD. Thus, as can be seen, the rental of the Beams cost nearly double the revenue received from registrations. This does not factor in the additional costs needed to run the telepresence program, including 3 complimentary registrations for "special helpers" to the Telepresence Chairs (described below), costs for student volunteer support, and costs for enhanced WiFi for the Beams.

**Telepresence Setup**

The conference primarily took place across three floors of the Denver Convention Center. Workshops and conference talks were held on the main floor (Figure 2). Plenary talks were held on a lower floor and the exhibit hall was on an upper floor. Beams were docked in a single location (labeled as "Docking Stations" in yellow within Figure 2) near the middle of the main floor, given its central location to the talks.

Some attendees had a local person bring items to decorate their Beam. This included clothing items, balloons, and paper signs that were taped onto the Beams. We also decorated several Beams ourselves with items mailed to us. This worked relatively well, though it did mean that remote attendees were stuck with the same Beam and could not easily change Beams. Sometimes this created issues if a Beam's battery was low on charge and a remote attendee wanted to switch Beams.

All remote attendees were asked to join a Slack group prior to the conference and then use it during the conference to report problems or ask questions about Beam usage. Separate channels were setup for technical questions and social questions, however, nearly all posts occurred in the #general
channel. The Slack channel worked extremely well and allowed SVs to monitor the needs of the remote attendees and respond to them quickly.

Student Volunteers

Student volunteers (SVs) and special helpers were crucial in running telepresence attendance.

Student volunteers. SVs provided assistance with any problems that remote attendees encountered, including moving Beams when they lost their WiFi connection, helping remote attendees when they became lost in the conference venue, finding places for attendees to watch presentations from in the rooms, and providing feedback on audio volume of the Beams.

We had 12 SVs assigned to telepresence at CHI. Each SV worked for 20 hours in total, and we had at least two SVs on duty at any one time throughout the conference. They received training in a telepresence orientation session the weekend before the main conference (either on Saturday or Sunday). During their shifts, SVs were instructed to be “on call” and pay attention to the Slack channel until a remote attendee called for help. It was unknown exactly when remote attendees would need help, so this “on call” style assignment allowed SVs to attend talks or interact with others when there were no issues to address. This assignment style worked extremely well; all SVs responsibly announced their shifts at their assigned start times, and addressed attendees’ problems promptly.
One SV volunteered remotely using a Beam because she could not come to the conference due to a Visa issue. During the coffee breaks, she used the Beam to roam around the exhibition halls and the hallways where coffee and snacks were served and visually reminded people of the talks in the upcoming sessions and how much time was left. She did so by posting messages on her Beam’s display and using paper signs. Her Beam was adorned with an SV t-shirt to show her role as an SV.

**Special helpers.** Special helpers set up the Beams and docking stations, tested WiFi connections throughout the conference venue, and helped with the two SV orientation sessions before the conference started. Throughout the conference, the helpers addressed the problems that required more hands-on knowledge of the Beams that the SVs could not handle.

**SV surveys.** All SVs filled out a post-conference survey about their experiences. All SVs found the use of the Slack channel and the “on-call” style assignment efficient.

“Slack was really helpful to keep track of issues and also allow us to attend session[s].”

“Training was very helpful. Other teammates were amazing!”

“Slack was a very easy and efficient way of keeping track of telepresence needs”

One SV noted that assisting Beams helped them socialize with others.

“Regardless of the problems with the wifi (sometimes), the Beams worked pretty well. Ah, I think the most positive thing about them is that they help you a lot at making friends and talking to people. Besides seeing this happening, I also heard it from the users :)”

Four SVs reported that the WiFi was the biggest issue for telepresence, and two reported that the robots’ volume was sometimes too loud or quiet.

“The Wifi is very crucial. Sometimes, they would disconnect and loose time because of that. Besides, another big problem is the elevators... They always loose their signal inside them. Finally, maybe if it was possible to setup like a "default volume" for them, that’d be nice. Some beams were too loud and
others, too quiet. Even though the users can control the volume, maybe it'd be a good idea to set a default for minimum and maximum volume. That way, they wouldn't be too loud or too quiet.”

One SV reported a difficulty in locating the robot and identifying the robot's number when remote attendees asked for help. Another SV commented that people signed up but did not use the robot all the time.

“There were too many inactive beams, which seemed to be a waste of resource[s]. Some people signed up for a beam for the entire day, but only used it for a small portion of it. There needs to be some kind of rules to regulate this.”

Based on the experiences, SVs made a few suggestions for the future. Three SVs wanted the telepresence reservation schedules integrated into Slack, two wanted to put numbers on the robots physically, and one wanted to put a tracker on Beams so that they could more easily locate the Beams.

“The beam numbers should be physically written on the robot as well (maybe on a sticker). I'd suggest keeping Slack, but it needs to have external content (e.g. schedule spreadsheet) somehow integrated directly into Slack instead of an external link (which forced us to leave Slack while on duty).”

One SV wanted to know more about the UI that remote attendees used to control the robot.

“It [would] be better if the student volunteers get hands-on with the beam for some time to help with the attendees’ questions regarding the user interface.”

Another SV suggested providing more extensive training for remote attendees so that they get better at operating Beams.

“Some users were very good at using them, others, not so much. I don’t know if you provide any kind of training before using the beams, however, if not, I think it would be a good idea to [ask] the users to play some game (find a game where you can use the same controls to move the avatar on it) and, by doing that, they would all be ready when using it. I'm proposing this because some users were having a hard time moving their beams. I think if you are not a gamer, than, “forcing” them [to play] some game before using the beam could help at that. That way, users won't [waste] time during the conference because of lack of skills at controlling them.”

**Benefits of Remote Attendance**

Remote attendees were generally grateful to be able to attend CHI remotely and really valued the opportunity to do so. Those with accessibility challenges were unable to attend in person because of mobility issues and the Beams turned conference attendance from an impossibility to a possibility. Those with Visa issues would have also been unable to attend without the Beams. In these cases, remote attendance was invaluable.

Two remote attendees attended workshops, one attended CHI4Good, and one attended a course. They had a very good experience working in small groups within the two activity settings. They were able to interact with local attendees, engage in group discussions, and perform individual work. The remainder of remote attendees took part in the main conference, mingled with attendees during breaks, attended talks, and toured the exhibit hall including CHI Interactivity. Primary activities were attending talk sessions and social mingling.
The following are selections of quotes from remote attendees in our post-conference survey when asked “What worked well about telepresence attendance?”

"bumping" into people and networking, feeling "present" at the conference and talks even though I was not there physically, interacting with attendees (new, colleagues, and friends) was the best part! I could still do many activities at work in [city] while attending CHI, no travel and board required (great for me since I have young kids)."

"Overall things worked well, and people were kind in helping out when moving around."

"easy interaction with people, smooth navigation in the conference center, clear camera view"

"Most of the logistics in terms of scheduling who would get what robot, when, and the SVs were super helpful about getting us where we needed to go!"

"Everyone was super helpful and certainly it seemed like there was a lot of support for this which was great!"

"I thought it was so cool and phenomenal to do this!!!"

Challenges with Remote Attendance
Remote attendees faced several problems that influenced their experiences negatively. When asked in the post-conference survey, "What did not work well about remote attendance?", responses fell into three main areas: audio, video, and network connectivity. These problems have all been previously reported for remote attendance at other conferences that used Beams; this includes Ubicomp/ISWC 2014 (Neustaedter et al., 2015), CSCW 2016 (Neustaedter et al., 2017), and CHI 2016 (Rae and Neustaedter, 2017).

Audio: Remote attendees faced problems hearing others in groups while social mingling outside of sessions during breaks. This included when in areas containing both small numbers of people as well as areas with large amounts of people. Remote attendees also had a difficult time hearing presenters during sessions. Audio quality was better when parked at the back of a session room, though this made it impossible to see the presenter's slides, given the low visual acuity of the Beam's camera. As the following quotes show, audio issues during talks was a major problem.

"auditory experience. It was not easy to hear the speaker even [sic] thoguh I tried different locations in the room."

"sound experience: I was not able most of the time to hear well during the presentations, in crowded rooms people were not able to hear me"

"This would have been a better experience if I could have understood any of the talks."

Video: Remote attendees tried to park near the front of the room during conference talks, however, it was sometimes still difficult to see what was shown on a presenter's slides given poor colour choices in the slides, angled viewing from the Beam, or the low visual acuity of the Beam's camera. Remote attendees also found it difficult to recognize people from a distance given the quality of the camera and video.
"I could not see the slides of presenters very well even when I parked in the front of the room and sometimes the talk sound was not good, it was not great to sit at a desk for many hours at a time so I took breaks for other activities in between"  

"It was impossible to see the slide presentations at the talks, which was unfortunate."  

"Hard to recognize faces of people until they were quite close; did not attend any sessions, but imagine it would be a problem reading presentation slides…"

**Network Connectivity:** Network speeds were tested on Saturday and Sunday of CHI and speed rates were \(~25\) Mbps download and \(~25\) Mbps upload. During Monday to Wednesday, network speeds dropped considerably to \(~3\) Mbps download and upload. Beams work best with at least \(5\) Mbps download and upload, however, a more desirable bandwidth is \(10\) Mbps up/down to avoid frequent problems. Without such bandwidth, Beams periodically drop their Internet connection or experience difficulties in driving. Such drops were experienced frequently by remote attendees, in particular, when driving between rooms.

"I know it's a hard problem to solve, but the connectivity issues were pretty rough, and they seemed to be most pronounced in the hallways outside of meeting rooms. Driving around during peak traffic time can be tricky as it is, dodging other attendees. But with an intermittent connection, driving gets very "jerky," complicating the issue."

"The Wi-Fi connectivity at the convention center was bad, which made any kind of navigation throughout the space nearly impossible without an escort that could help you get out of tricky situations."

"It's difficult to know exactly how the telepresence robots are going to fair before the conference starts, but I think ensuring that the robots have a dedicated Wi-Fi connection for their use would be a good start."

**Conclusions and Recommendations**

Based on our observations and survey responses, we offer the following recommendations for CHI 2018 and other ACM conferences.

**Better Internet connectivity.** It is clear that better Internet connections are needed if remote attendance is to be offered at future CHI conferences. Lessons from CHI 2016 (Rae and Neustaedter, 2017) and CHI 2017 show that Beam data rates need to be above \(5\) Mbps for download and upload or significant problems occur which results in many complaints from remote attendees. Given that this is a known issue with known solutions, such WiFi connections should be setup *prior* to the conference, rather than setting them up as a reaction to poor bandwidth and problems being reported by remote attendees *during* the conference.

**How many Beams is the right number?** It is difficult to gauge how many Beams is the "right" number to have on-hand to support telepresence attendance. Remote attendance numbers from CHI 2016 suggested that CHI 2017's 14 Beams would have been completely utilized. The uncertainty posed by possible travel bans and Visa issues might have even increased the need for telepresence attendance and Beam usage at CHI 2017. However, this was not the case as at least half of the Beams sat unused at any one time during the conference. Having only 8 Beams available at CHI 2017 likely would have sufficed, yet, again, it would be hard to determine this number *a priori* since people may be "no-shows" or change their robot usage plans somewhat spontaneously.
The model of assigning a Beam per person per day helped attribute to a low utilization of Beams since remote attendees most often did not attend for the entire day due to time zone issues, fatigue from driving a Beam, and interest in only some sessions. We suggest alternative Beam assignments, such as having people sign up to use a Beam during particular sessions or for a half-day at a time. This would require a different pricing model for registration that allows people to pay for shorter time segments than a single day or the full conference.

**Offer alternative remote attendance options.** Like past conferences utilizing Beams for remote attendance (Ubicomp/ISWC 2014, CSCW 2016, CHI 2016), remote attendees faced audio and video challenges within talk sessions. Beams performed much better during small group interactions in workshops. This shows that Beams are good for supporting portions of CHI that involve small group activities and interactions, but are less good for viewing conference talks.

These findings suggest strongly that alternative remote attendance options are needed for supporting remote attendance at CHI and other similar conferences. Beams are but one solution for helping support remote attendance but they do not support all situations; in fact, alternative technologies would better support several portions of CHI. This follows from similar recommendations at CHI 2016 (Rae and Neustaedter, 2017). For example, remote attendees would highly value talks that are streamed online over viewing talks through a Beam. Talks are difficult to see using a Beam and this has been a reported issue across several ACM conferences. Streaming of talks could be done through specialized software setups (similar to the system that is currently being used to record presentations), however, there may also be alternative solutions that include lightweight forms of live streaming. For example, future conferences could experiment with using a dedicated Skype computer at the front of the room (using a high quality webcam) or having multiple people livestream sessions using apps such as Facebook Live. Internet bandwidth rates should be considered for such solutions.

**References**

